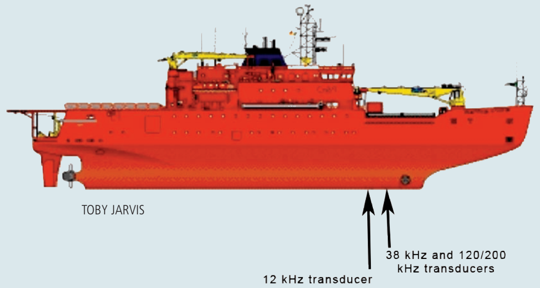
The Heard Island *echo*system: eavesdropping on the food web



The subantarctic waters of the Heard Island and McDonald Islands (HIMI) region support a diverse range of living organisms, each of which plays a role in the complex web of interactions that make up the marine ecosystem. In the summer of 2003-04, we set out on the *Aurora Australis* to improve our understanding of this web using echosounder data collected as part of the larger 'Heard Island Predator-Prey Investigation and Ecosystem Study' – 'HIPPIES' for short (*Australian Antarctic Magazine* 7: 6-7).

A detailed understanding of the HIMI food web is important because Australia oversees commercial fisheries for Patagonian toothfish and mackerel icefish in the region. The overall aim is to manage fishing so that the impacts on the ecosystem are minimised.

We know that the marine ecosystem is fuelled ultimately by energy from the sun and nutrients in the water, and that this energy enters the food chain through microscopic phytoplankton drifting in the sunlit surface waters. We also know that this energy passes through a diverse range of drifting animals (zooplankton), which in turn are consumed by fish, seabirds and marine mammals. However, we know relatively little about where each type of organism is found, how many there are, and who eats whom and when.

Investigations of distribution and abundance of marine organisms have typically been made by towing nets through the water column and counting what is caught. There are two main problems with nets, however. Firstly, net catches don't necessarily reflect what is down there. Secondly, the area that can be surveyed this way is tiny. This is where echosounding comes in. By sending pulses of sound into the water and recording the timing and strength of the echoes that return, we can build up a better picture of distribution and abundance. This is because even the smallest organisms in the water column can give off a detectable echo if the frequency of the sound pulse is right and the equipment is sensitive enough. In short, you can literally hear where these things are.

The *Aurora Australis* is equipped with computer-controlled, state-of-the-art echosounders mounted in the hull (*Australian Antarctic Magazine* 2: 9-10). During HIPPIES, we sent pulses of sound ('pings') into the water column at frequencies of 12, 38, 120 and 200 kHz[1]. As the ship steamed along its defined transects, the 12 kHz sounder pinged roughly every six seconds, while the other sounders pinged roughly every second (about 8 million pings in total). Following each 12 kHz ping, the equipment recorded the echo strength in decibels every 75 cm as the sound wave travelled down into the depths. At 38, 120 and 200 kHz, the echoes were recorded every 20 cm down through the water column. We ended up with about 40 billion echo measurements, taking up 250 gigabytes of computer memory, that described the location of reflective objects throughout the water column wherever the ship went.

A primary analysis of this mountain of data is nearing completion. The first task has been to display images of the reflected sound on a computer (see the echogram pictured) in much the same way that a digital camera does for reflected light. Each echo measurement represents a pixel that is colour coded according to its decibel value and positioned according to its depth and location along the ship's track. The second task has been to use these images to help answer questions about how the ecosystem works. This is an altogether trickier proposition.

The data are first prepared and cleaned – by removing background noise, for example – for further analysis. The 'post-processed' data can then be analysed in a number of ways, depending on the questions being asked.

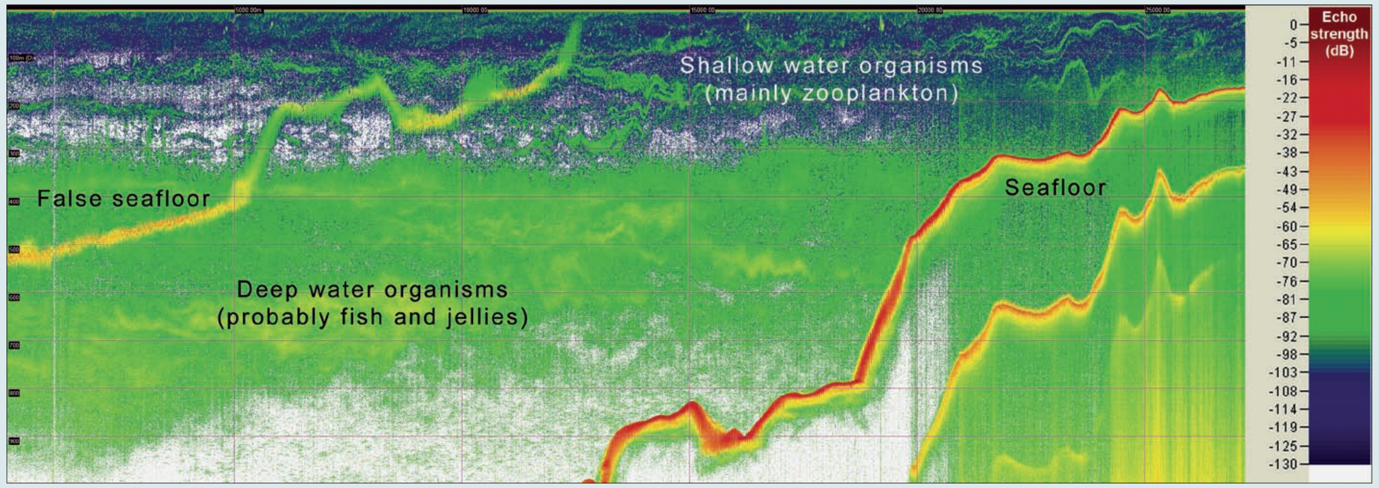
At this stage we are asking:

- Are there any noticeable zones in the HIMI marine region with different numbers and/or types of organisms and interactions?
- If so, what types of organism do we find in each zone, how abundant are they relative to each other, and how do they relate to each other and their environment?
- What do these findings tell us about how best to manage the commercial harvesting of Patagonian toothfish and mackerel icefish?

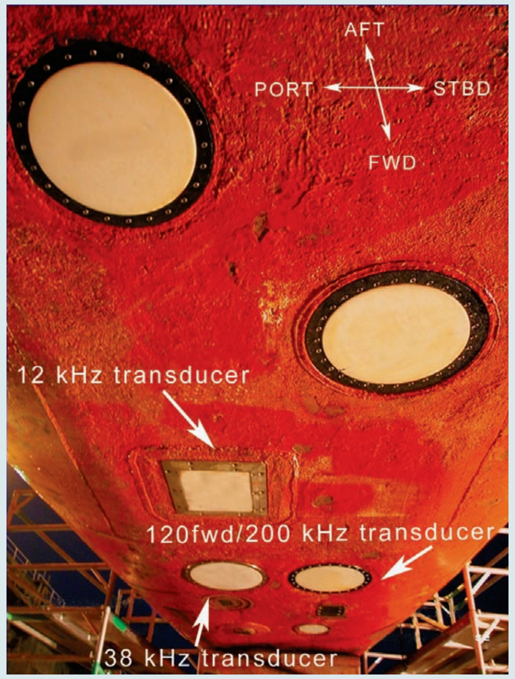
In terms of general numbers of organisms, we are simply calculating the total amount of echo energy in a given area using a technique known as 'echo-integration'. If we assume that this is due entirely to organisms in the water column, we can explore whether or not certain areas support more organisms than others.

As for which types of organism are responsible for this echo energy, we need to partition the energy by species type (e.g. zooplankton, jellies, squid, fish) and then look again at their individual distributions. This requires detective work using a combination of approaches.

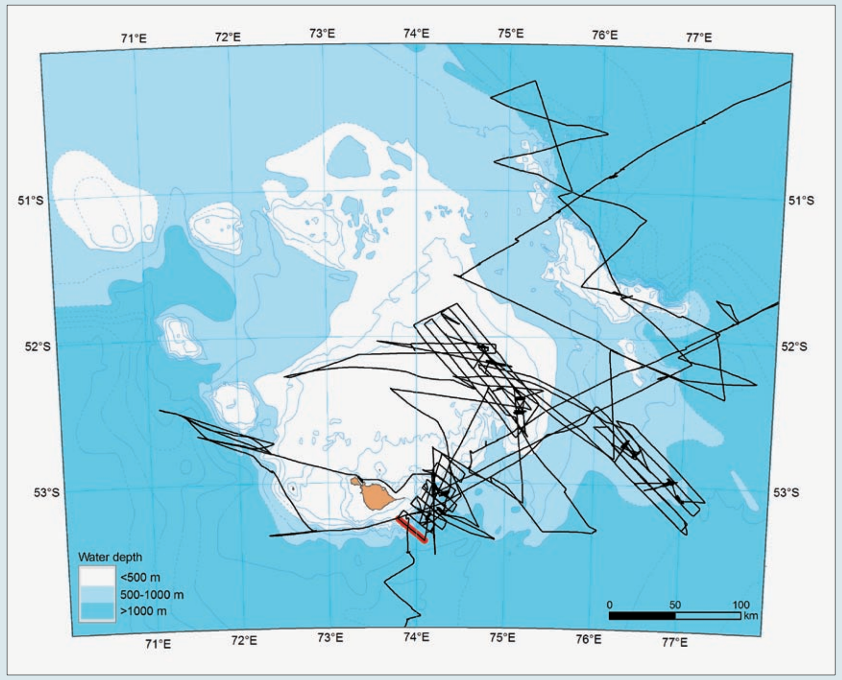
Firstly, we can get an idea of where each species type might be on the echograms by seeing what was caught in nearby trawls. This is called 'ground truthing'.



An example echogram from the 38 kHz echosounder. The vertical height represents 1000 m through the water column. The horizontal width represents 27 km along the ship's track. Colours represent echo strength in decibels (dB), where red is the strongest echo and blue the weakest.



The echosounders on the RSV *Aurora Australis* are mounted in the hull and point downwards. During HIPPIES, data was collected from the sounders labelled '12', '38' and '120fwd/200'.



The ship's track during HIPPIES. The red transect shows the location of the example echogram.

Secondly, we can assign certain strengths of echo energy to certain species types, and filter the echograms based on this. For example, a fish with a gas-filled swim bladder will likely give a much stronger echo than a gelatinous jellyfish.

Thirdly, we can use the way objects reflect sound differently at different frequencies to filter the echograms. For example, a fish with a swimbladder typically gives a stronger echo at 38 kHz than at 120 kHz, while the opposite is true for many zooplankton.

Finally, we can use image-analysis techniques to encircle clusters of echoes on each echogram. By describing each of these clusters in terms of size, shape and depth, and grouping them using multivariate statistical techniques, we have a technique that is similar to ground-truthing but less subjective.

Through the course of these analyses we are gaining a better understanding of the biological structure of the HIMI marine region. Visual analysis of the echograms is revealing complex and extensive aggregations of organisms and highlighting interactions between different types of acoustic scatterers that vary depending on location and time of day. Echo-integration and energy-partitioning analyses are allowing us to quantify these observations in an ecologically meaningful way. As the first sets of results come in from each of the projects within the HIPPIES study, we can look forward to gaining new biological insights and a greater ability to simulate, and therefore mitigate, the potential impacts of commercial activities in the region.

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[1] The hearing range for humans is about 0.05-16 kHz. For whales it is about 0.02-200 kHz.